Influences of international airliner overflights on Japanese airspace efficiency

Tomoyuki Kozuka [1] and Miyazawa Yoshikazu[1]

[1] *Department of Aeronautics and Astronautics, Graduate School of Engineering, Kyushu University*
744 Moto-Oka Nishi-ku, Fukuoka, 819-0395 Japan

Abstract

In light of the increasing number of overflights through the Fukuoka flight information region (FIR) in recent years, we attempt to analyse the effects of overflights and propose a solution to associated problems. In this study, Collaborative Actions for Renovation of Air Traffic Systems (CARATS) Open Data files are used to analyse the effects of overflights. The CARATS Open Data which include the time histories and position data of commercial flights within the Fukuoka FIR, are obtained by the Japan Civil Aviation Bureau (JCAB) from radar tracks. Examination of the data shows that overflights sometimes occupy their optimal altitude during cruise, preventing airliners on international flight paths from Japan from climbing to required altitudes and decreasing their cruise altitudes. Data extracted from crowded situations are analysed in order to propose a solution to the conflict problem.

Keywords: overflights, airspace efficiency, altitude conflict, CARATS Open Data, international flight.

Introduction

Air traffic is increasing globally, and especially in Asia. Following a report on Collaborative Actions for Renovation of Air Traffic Systems (CARATS), air travel demand is anticipated to rise by a factor of 1.5 from 2005 to 2027 [1]. If air traffic continues to grow at its current pace, new problems will arise and Japanese airspace efficiency will be adversely affected. One such adverse effect will be an increase in cruise altitude conflicts between overflights and international flights originating in Japan. To mitigate such problems, it is necessary to analyse the oversight situation and assess measures for addressing the conflict issue.

To date, not much research has been conducted on overflights. Outside of Japan, only a few papers focussing on both overflights and conflict have been published [2], [3]. Within Japan, the subject of conflict altitude with respect to international flights is studied at the university and institute levels [4]-[6]. Because the country is an island with a significant north-east and south-west extension, overflights between Asia and the North Pacific can easily affect flights originating in the Fukuoka FIR. However, there have been few studies of overflights over the non-oceanic Fukuoka FIR and few solutions have been discussed. Therefore, this study examines overflights over Japan and proposes one solution to the aforementioned problems.

The purpose of this study is to reveal the influences of international airliner overflights on other flights in order to develop a potential solution for decreased efficiency. The proposed solution will be examined in the next study.

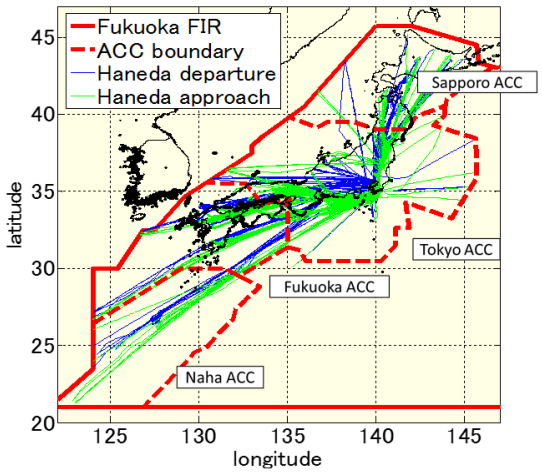

Fig. 1: Radar tracks from CARATS Open Data

Table 1: Outline of CARATS Open Data

TERM	7–13 May 2012 9–15 July 2012 3–9 September 2012 5–11 November 2012 7–13 January 2013 4–10 March 2013 (total 42 days)
TARGET	Airliners (only IFR)
COUNT	About 3,600 [aircraft/day]
PARAMETERS	Time, Hypothetical flight-number, latitude, longitude, Aircraft type
DATA CYCLE	About 10 [seconds]

CARATS Open Data

Processing of CARATS Open Data

This study used "CARATS Open Data" files to analyse international airliner overflights. The data files include time histories of commercial flight position data within the Fukuoka FIR, as shown in Fig. 1. An outline of the data is provided in Table 1. The data were recorded over a total of 42 days at one week for each odd-numbered month from May 7, 2012 to March 10, 2013.

In general, radar track data contain various errors; CARATS Open Data include both errors and unexpected values. Shigetomi et al. [7] analysed the accuracy and documented errors in CARATS Open Data. In our study, we used a four-step pre-processing methodology to reduce the number of errors and unexpected values. In the first step, all values with position error are removed by calculating the three-axis acceleration of an aircraft from three sets of position data and removing the third data set when the acceleration exceeds a threshold. In the second step, accurate estimation of time, time included after the decimal point is estimated in terms of acceleration using a linear search method because time of CARATS Open Data is rounded off to an integer. In the third step, unexpected values are eliminated. If unexpected values of altitude data occur in which the vertical rate exceeds a threshold value, they are removed. In the fourth step, hand-control processing, a method discussed in the next subsection is used to identify conflicts; in cases where such conflicts are caused by unexpected values (and only in such cases), the corresponding data are removed.

Categorizing flights

Flight data from 42 days of CARATS Open Data are divided into the four patterns shown in Table 2 and plotted by pattern in Fig. 2. Each flight has an approximately unique route, as shown in Fig. 2. The total number of flights per day and the number of flights by pattern are shown in Figs. 3 and 4, respectively. It is seen that each of these figures remains fairly consistent on a daily basis, with a daily average total number of flights of approximately 3,486, about 60% of which are domestic. The effects of overflights is analysed using categorised flights.

Analysis of overflights

Air Traffic Control in Japan

For the purposes of this paper, overflights are defined as flights between foreign countries via Fukuoka FIR. This study addresses the conflict between overflights and international flights originating in Japan; this is prevalent because each type of flight must follow a predetermined transfer as much as possible, which tends to increase the likelihood of conflict. In order to describe the conflict, we use rules of international flights based on "Aeronautical Information Package Japan (AIP JAPAN)" [8] published by the Civil Aviation Bureau JAPAN, Ministry of Land, Infrastructure, Transport and Tourism. AIP JAPAN can be get at the website (requires login) of Japan Aeronautical Information Service Centre (AIS JAPAN).

There are many waypoints on the boundary of Fukuoka FIR. Westbound flights are expected to have Europe or Asia as destinations, while eastbound flights are expected to be heading to North America. When international airliners go to North America, they must pass through a specific gateway using one of four route patterns. Recently, airliners have been selecting patterns PACOTS or UPR in preference to NOPAC.

Table 2: Flight patterns

Number	Pattern
1	Domestic lines
2	International flights from overseas
3	International flights going overseas
4	Overflights

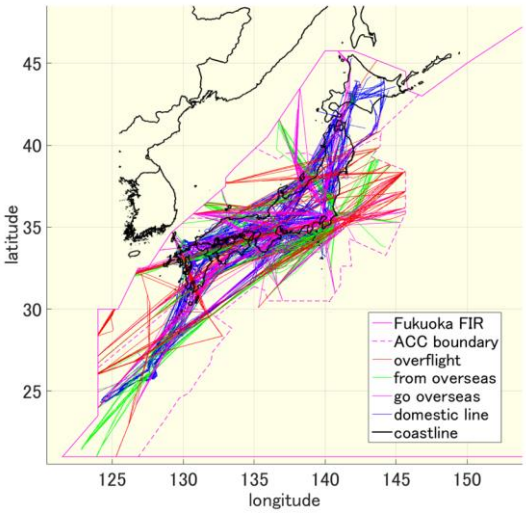

Fig. 2: Radar tracks for each pattern (7 May 2012)

Analysis of categorised flight data

We analysed overflights in terms of three parameters: 1) selected altitude, 2) selected route and 3) separation between aircrafts.

Selected cruise altitudes, or the altitudes at which aircrafts fly the longest, are indicated in Fig. 6. Domestic lines often choose a cruise altitude of around 39,000 [ft]. The altitude distributions illustrated in Fig. 6 show that international airliner flights (go overseas and from overseas) bound for Asia or Europe outnumber those bound for North America. This can be inferred from the fact that westbound flight tracks have even flight levels (i.e. dividing the altitude by 1,000 produces an even number), while eastbound flights have odd flight levels (dividing the altitude by 1,000 produces an odd number). This distribution is seen in the altitude range 29,000-41,000 [ft] and is possible only for planes equipped for reduced vertical separation minimum (RVSM).

Selected routes are shown in Fig. 7. The routes are classified into four directions: headings 040-135, 135-225, 225-315 and 315-045 (where the units are magnetic compass degrees). The small arrows in Fig. 7 indicate wind speed and direction at the altitude corresponding to an atmospheric pressure of 250 [hPa]. The colours of the respective flights encode the general direction of each route. It is seen that most eastbound flights are on the south side of the centre, while westbound flights tend towards north of the centre. This tendency is due to the location of strong jet stream. The averages and standard deviations of the number of flights passing each waypoint are shown in Fig. 8. Waypoints near the boundary of Fukuoka FIR are divided into four groups for convenience and, as is seen in Figs. 7 and 8, most of the flights pass western waypoints.

Finally, we analyse separation between aircrafts for ‘ADNAP’, one of the eastern waypoints, and ‘BULAN’, one of the western waypoints. The ADNAP results are shown in Figs. 9 and 10; BULAN results are shown in Figs. 11 and 12.

In Fig. 9, green lines indicate overflights while red lines indicate international flights originating from Japanese airports. International departures regulate their passing time through ADNAP based on the schedule of overflights directly passing the waypoint. In Fig. 10, the green and red points in the top diagram indicate the altitude and passing times through ADNAP of overflights and international flights from Japanese airports, respectively. The bar graph below indicates the time separations of aircraft at all altitudes, and the bottom graph indicates the time separations of aircraft by altitude. These figures show how separation is assigned by altitude to avoid conflict; altitude conflict occurs when an aircraft with an assigned separation occupies a particular altitude into which another aircraft, below its requested altitude, levels off.

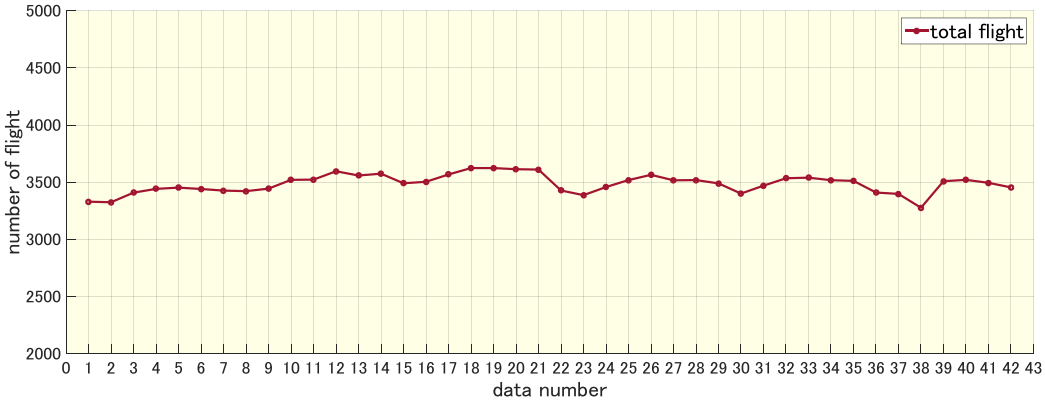

Fig. 3: Total number of flights by day (42 days)

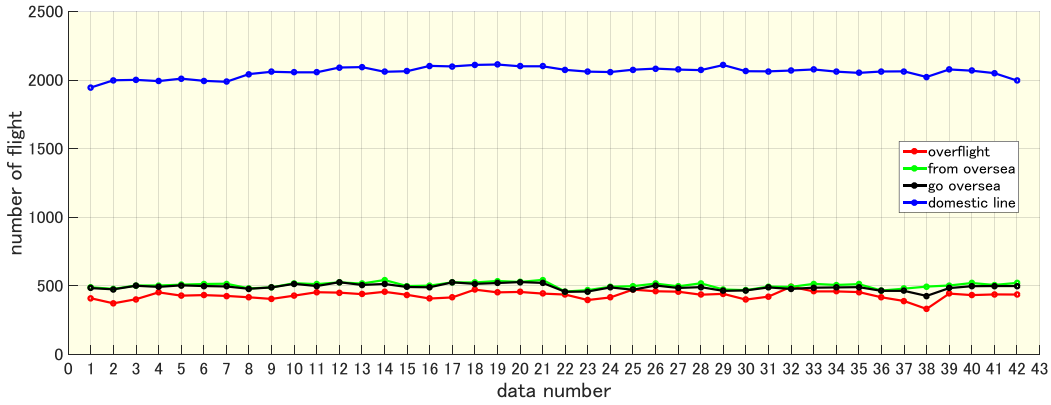

Fig. 4: Numbers of flights by flight pattern (42 days)

Table 3: Route patterns

Route	Explanation
NOPAC (North Pacific)	The route that links the North America to Japan set in the North Pacific as an oceanic airway.
PACOTS (Pacific Organized Track System)	The variableness course set by wind on the day.
UPR (User Preferred Route)	Airliners set a course every flight.
DARP (Dynamic Airborne Reroute Procedure)	It is the variableness course based on requirement during a flight.

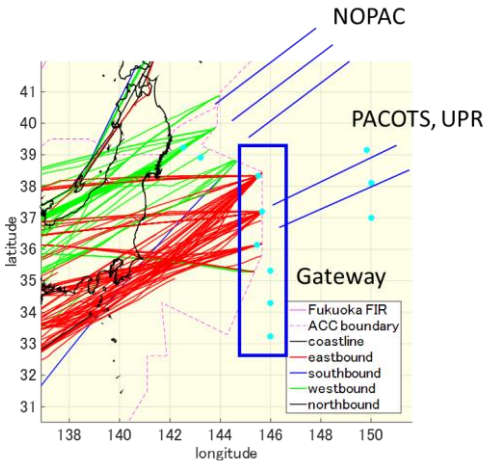

Fig. 5: Route patterns (7 May 2012)

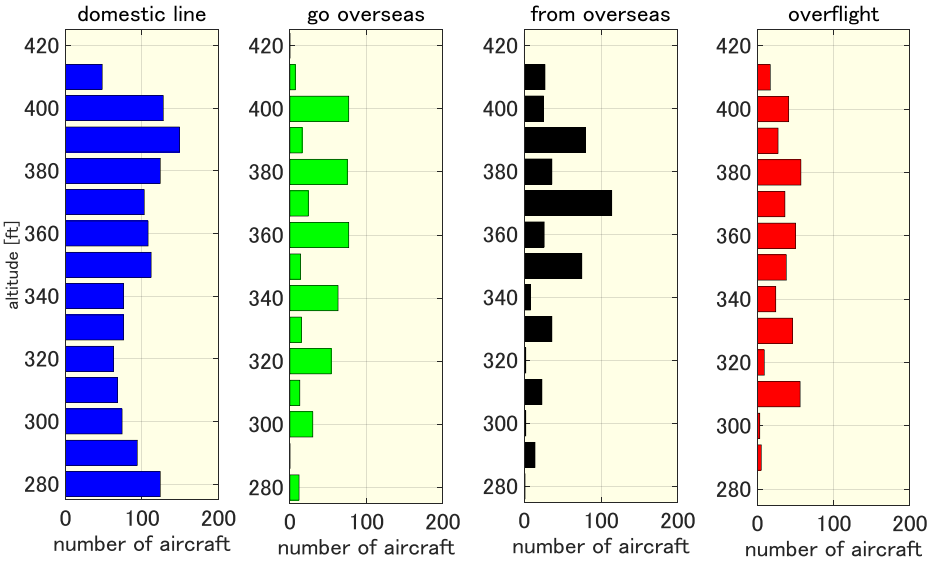

Fig. 6: Selected altitudes (7 May 2012)

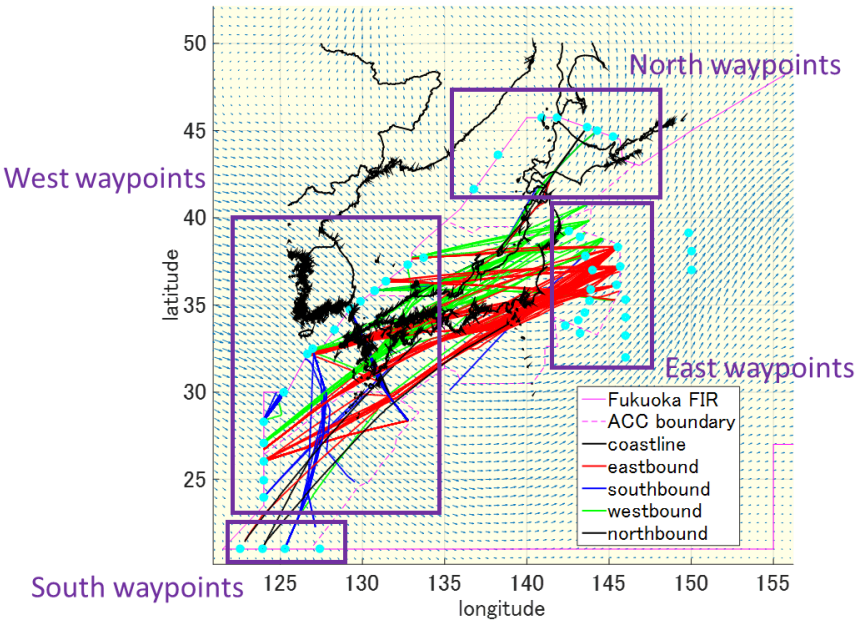

Fig. 7: Selected routes and categorised waypoints (7 May 2012)

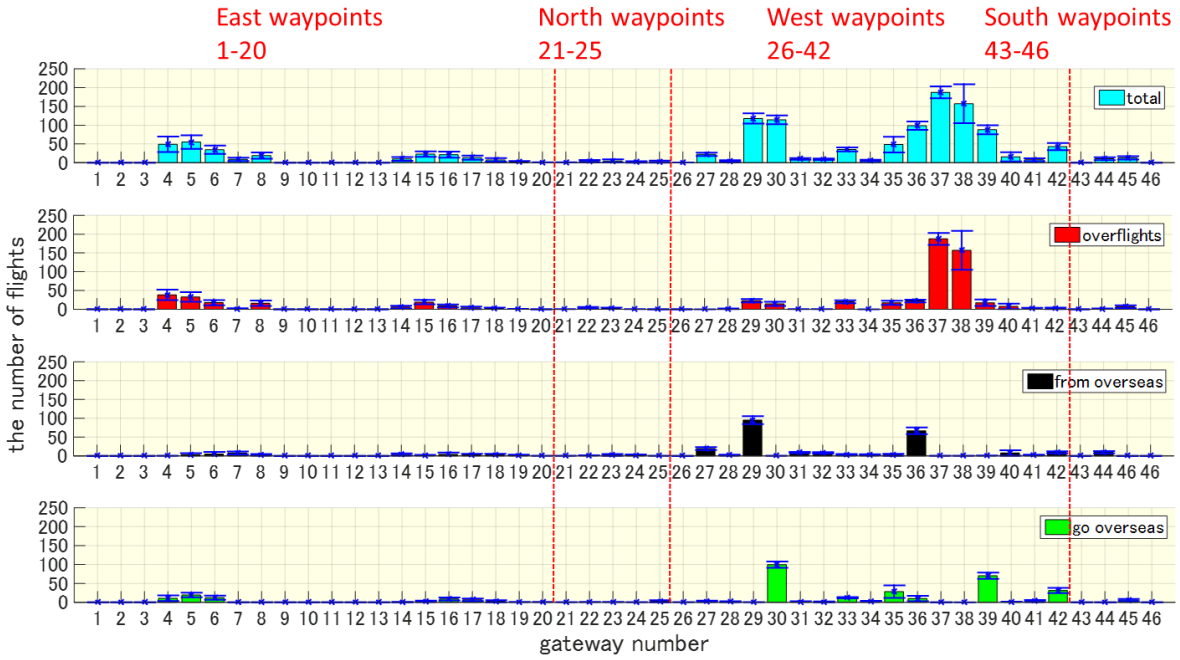

Fig. 8: Average numbers and the standard deviations (42 days) of flights passing each waypoint

From Fig. 11, it is seen that both overflights and international flights departing from Japan cross BULAN, making interference much more likely. Although the separation distribution in BULAN is similar to that in ADNAP, in the former case there are many more international flights than overflights.

Comparison of the results derived for the respective waypoints shows that a narrow separation of overflights increases the possibility of decreasing the efficient altitudes of international airliner flights from Japanese airports.

Summary

Statistics on the timing, altitude and direction of overflights over Japanese airspace and the effects of overflights on international flights were obtained by analysing CARATS Open Data. From these data, figures on separation at crowded waypoints were derived. Based on this analysis, we propose a solution for the problem of altitude conflict using time control of passing waypoints. In future work, we will attempt to implement our proposed solution in order to quantify its effectiveness.

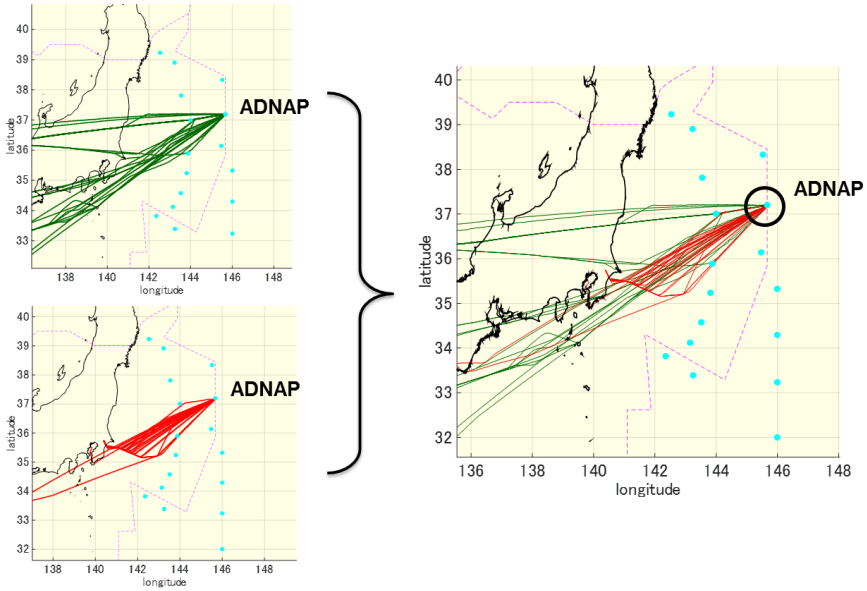

Fig. 9: Radar tracks of overflight and international flights from Japan to "ADNAP" (7 May 2012)

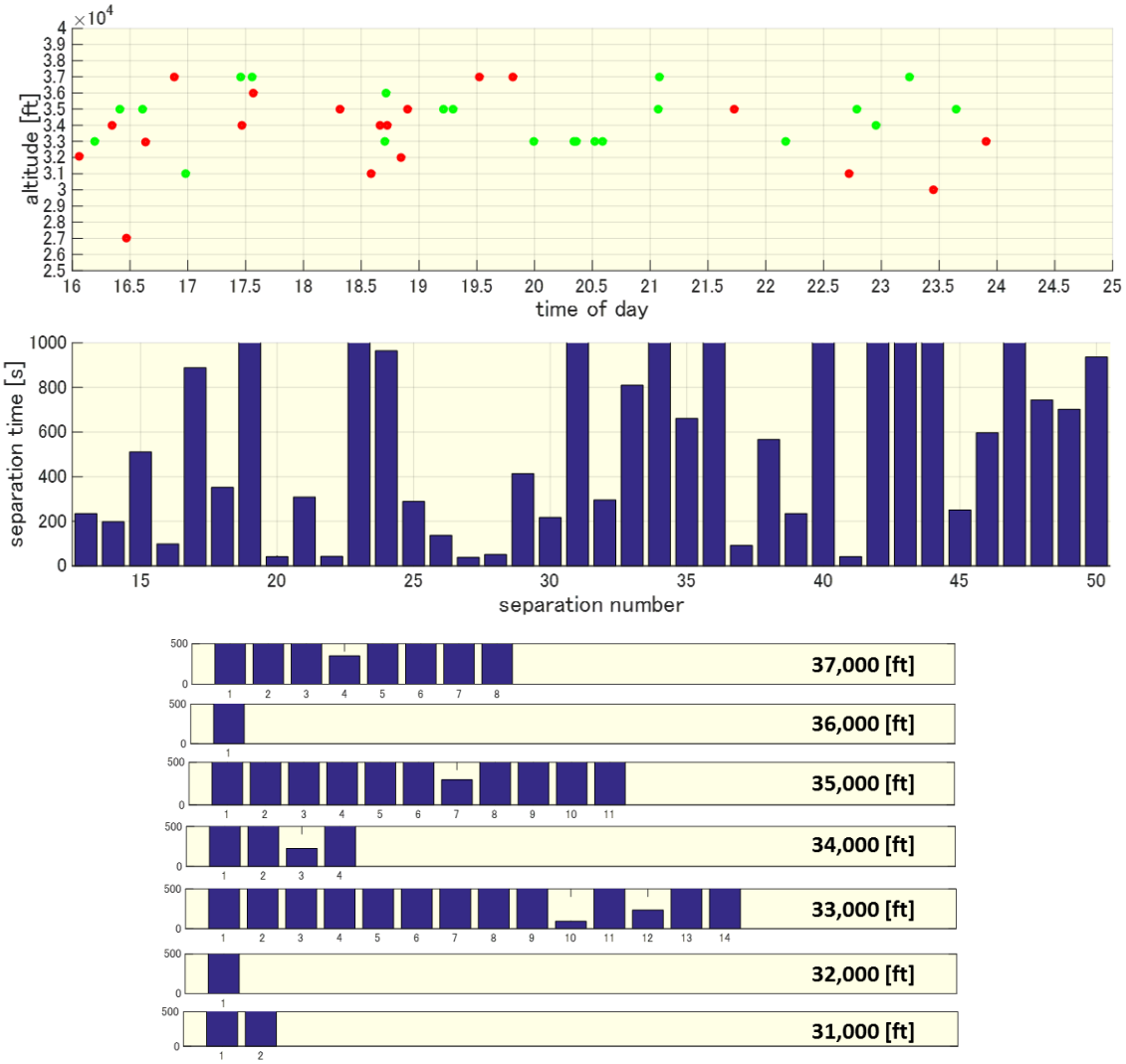

Fig. 10: Selected altitude and separation of overflight and international flights from Japan (7 May 2012)

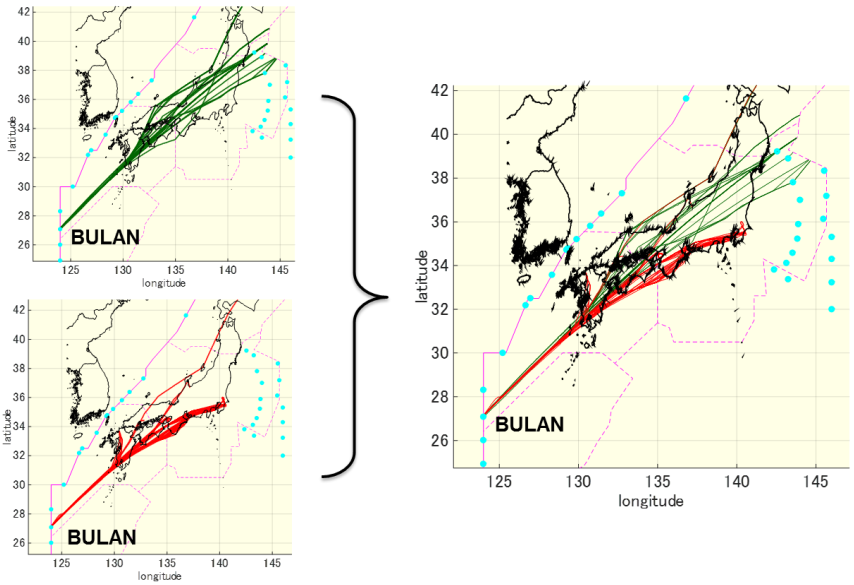

Fig. 11: Radar tracks of overflight and international flights from Japan to "BULAN" (7 May 2012)

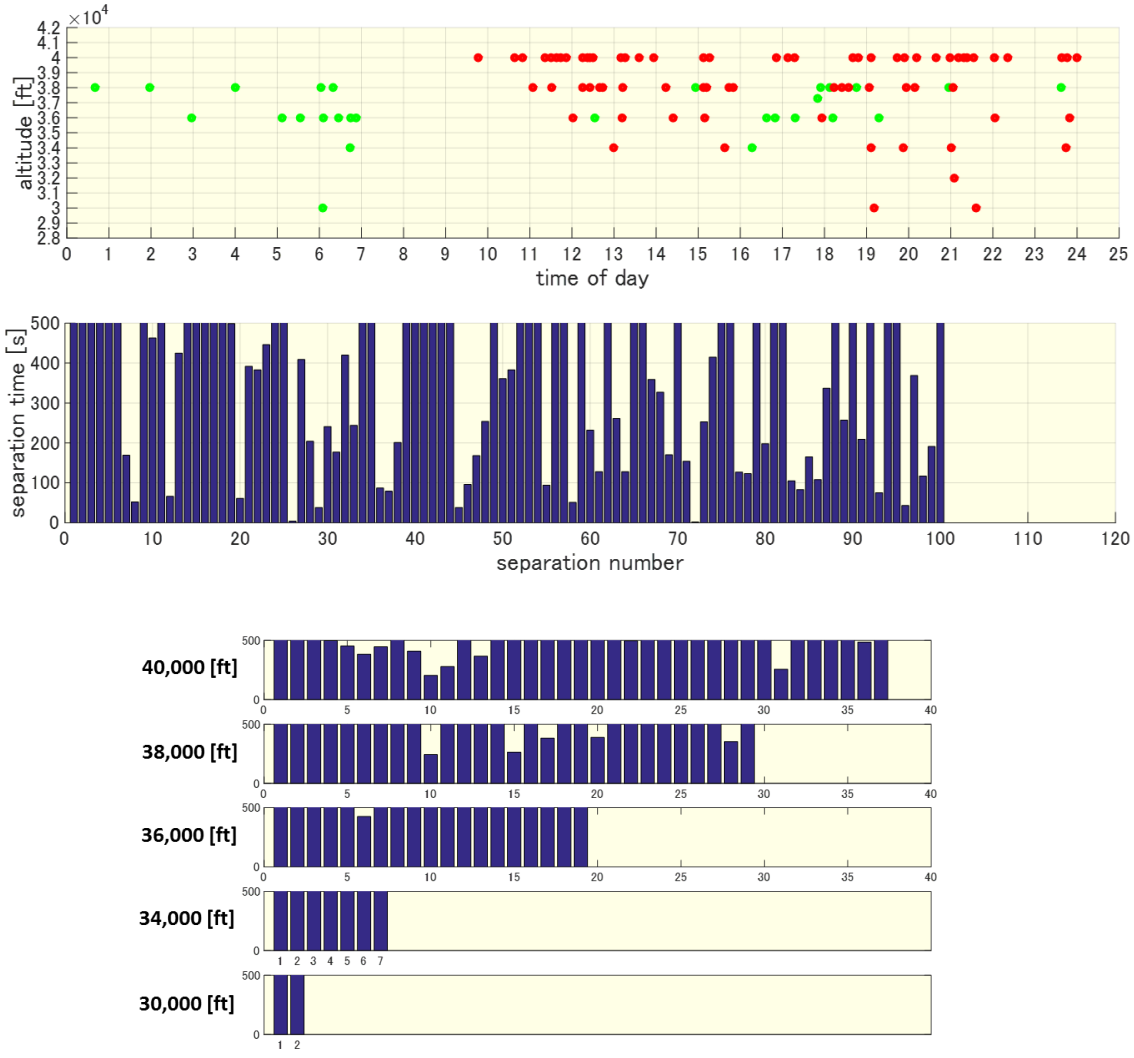

Fig. 12: Selected altitude and separation of overflight and international flights from Japan (7 May 2012)

References

1. Study Group for the Future Air Traffic Systems, "Long Term Vision for the Future Air Traffic Systems, CARATS Collaborative Actions for renovation of Air Traffic Systems", URL: http://www.mlit.go.jp/ common/000128185.pdf, 2010.

2. Nathan, A. D., Richard, B. and James, M. H. II, "Distributed conflict management in en route airspace: human-in-the-loop results", *24th Digital Avionics Systems Conference*, October 30, 2005.

3. Jeffrey, H., Thomas, P., Joey, M., Matthew, M. and Christopher, C., "Human/automation response strategies in tactical conflict situations", *24th Digital Avionics Systems Conference*, October 25-29, 2009.

4. Sumiya, M., Fukushima, S. and Fukuda, Y., "Comparison of optimal routes with PACOTS in Pacific Ocean", (in Japanese) *IEICE Technical Report*, 2011.

5. Kinoshita, H. and Hirata, T. "Simulation analysis of conflict between international departure flights from Japan and overflights", *the 52nd Aircraft Symposium*, 2014.

6. Hirabayashi, H., Fukushima, S. and Okada K., "A study of branching UPRs from Pacots track 2", *Electronic Navigation research institute papers*, No.132 January 2015.

7. Shigetomi, S., Kozuka, T., Higuchi, Y., Yoda, K. and Miyazawa, Y., "Evaluation of CARATS Open Data Accuracy" (in Japanese), *JSASS collection of annual convention lecture*, 46, 5p, 2015-04-16.

8. The Civil Aviation Bureau JAPAN, Ministry of Land, Infrastructure, Transport and Tourism, "AIP JAPAN", URL: https://aisjapan.mlit.go.jp/Login.do.